Some Implications of the Development of a High Biotechnology: The Perspective of Economic History[1, 2]

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I didn't have to hear the foregoing presentations to know that this conference would be a celebration of the promise of biotechnology. The very calling into existence of the conference and the encouragement we received from Governor Celeste attest to the fundamental optimism with which we view biotechnology. I am all for it, and I am glad to be a part of it. It is good for our country and it is, perhaps, especially appropriate to Ohio at this time.

Yet, in the longer perspective of global time, the rites of passage of economic history involved as much or more of the push of necessity as the pull of opportunity. And they always involved as much or more of agony as of ecstacy, at least at first.

By my reckoning, it is convenient to recognize three such passages: the first is the agricultural revolution, the second is the industrial revolution, and the third is the technological revolution, of which this biotechnology is such an important part.

Neither the agricultural revolution nor the industrial revolution were much welcomed by the participants. The coming of agriculture, first necessitated by population pressures in some parts of the world about 13,000 years ago and still going on in a few parts of the world today, changed the free-roaming, hunting-foraging life that humans had enjoyed for at least 40,000 years into a work-a-day world of drudgery. Agriculture meant that Adam and Eve were expelled from their Garden of Eden and were condemned to a life of labor: *In the sweat of thy face shalt thou eat bread,* as the Bible puts it.

Agriculture also meant that humanity gained greater managerial control over economic productivity, and, after achieving some efficiency, it made vastly larger populations possible. That the coming of agriculture eventually came to represent a giant step forward in human progress was probably never appreciated by the Adams and Eves who reluctantly had to give up their old ways of life in their Gardens of Eden.

Similarly, the industrial revolution, which began in Britain about 200 years ago and is still being hotly waged in the developing economies of the world today, was not initially much welcomed. The social disintegration, the environmental destruction, and the personal dehumanization that it caused are well and amply documented, and the various fascist, socialist, Marxist, Maoist conflagrations that it sparked into existence are still flaring up today.

But industrialism also enlarges humanity's managerial control over economic productivity, and once it becomes established and efficient, it makes vastly larger populations and greatly increased standards of living possible. That industrialization is a giant step forward in human progress was probably never appreciated by the child laborers, the robotized workers in the *satanic mills,* and the armies of the hopelessly unemployed who experienced the early days of industrialism as a *grist mill of human degradation.*

Can we expect a more benign transition during the current technological revolution? This is the major question underlying this conference today. Some doubts were expressed in the Cullis, Wagner, and Janson-Pavlakovic papers presented earlier. Our anxiety about *Big Brother* super computers operated by our governments, about the destruction of our gene pool through radiation or chemistry, about Three Mile Island or Bophal-type environmental disasters happening or happening again, about an *Andromeda Strain* threatening pandemics, or, ultimately, about a nuclear holocaust putting an end to us all, indicates that technology does not come into our lives without some second thoughts.

The fact that technology, once it has the wrinkles ironed out — pocket calculators, coronary by-passes, airline reservations computers, and teflon coatings come to mind — vastly enhances humanity's managerial control over economic productivity may be a lost promise to the victims of its distresses. But the technological revolution is different from both the agricultural and the industrial revolutions in one important way: technology itself involves practically no substance; it is intangible, an ephemeral figment of the mind.

This means that the technological bases of economic production do not need to replace the previous industrial or agricultural ones. By contrast, when agriculture supersedes hunting-foraging, the farmers force the hunter-foragers off the land and into oblivion. This is what the ancient Babylonian farmers did to the wandering Mesopotamian tribes over ten thousand years ago, what the European settlers did to the American Indians just a few centuries ago, and what the Japanese immigrant ranchers are doing to the native jungle peoples along the Amazon River today. Industrialization was equally intolerant in its victory. The introduction of industrial factories, iron and steel, and fossil fuels annihilates handcraft manufacture and agriculture and the economic and social structures associated with these so completely that handcrafting remains only as an entertaining oddity and tourist attraction, where it remains at all.

Technology is also a force for change, but it is not built on the ownership of land or physical capital. Therefore, it need not be a death sentence on the existing land and capital owning economic order. Instead of having to replace it, technology insinuates itself into and onto the older order, altering it, enhancing its economic productivity, but not necessarily getting rid of it. Farmers, instead of being threatened by technology, see it as their most important opportunity for greater yields and greater

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[2]Edited text of an address given at the symposium.

profits. Industrialists, likewise, and most urgently in Ohio, see technology as their main key to unlocking the trap of obsolescence and stagnation. Even workers, who have suffered the most conspicuous displacements through technology and who have put some of the most violent episodes against new technologies on the record of economic history — the saboteurs and the Luddites come immediately to mind — have, nevertheless, benefitted mightily from them, as mechanical energies and modern systems relieved them of much of the physical *sweat* that has been our earthly destiny since our expulsion from the Gardens of Eden.

This is clearly implied in the Cullis, Janson et al., and Wagner presentations we heard this morning and in the luncheon address by Dr. Eichel we heard this noon. And this is the source of the almost unanimous spirit of welcome with which technology is greeted in progressive circles and with which it is greeted here today.

Technology's intangibility presents some other variances from previous economic orders. Unlike land and capital, the same technology can be owned by two or more people at the same time. That is, the knowledge that I own can also be knowledge that you get to own, without my having to give up my ownership of that knowledge. (When students learn from teachers, the teachers are not drained of their knowledge.) This marvelous, almost infinite, and relatively inexpensive multiplicability of technology is utterly different from the physical fixity of land, capital, and hours of labor, where what I own you can't possibly own at the same time.

This means that technology is the most accessible of all factors of production. This also makes it the most compatible with free enterprise and democracy, because no permanent technological elite comparable to the landed aristocracy or to capitalism's family fortunes is likely to develop. Stanford and M. I. T. cannot monopolize hi-tech; neither can Silicon Valley or Route 128. More than ever before, since the agricultural and industrial revolutions, personal intelligence and vigor — not necessarily bequeathable quantities — will determine the ownership of technology and, thus, the distribution of income, social status, and power. Furthermore, since technology is, by nature, transitory, accumulations based on technology are not likely to be long lived. Social mobility and individual opportunity will be greatly increased in an economy that is largely based on technology.

Also, since technology is intangible, proprietary claims on it are difficult to enforce. Land may be fenced off and physical capital may be patrolled by security guards. But, patents, copyrights, and strictest secrecy notwithstanding, technology lends itself nicely to borrowing, imitation, replication, and theft. It can be carried away in the brain, the way the plans to the British spinning jenny were carried to the infant textile industry in Rhode Island two centuries ago, in the head of an apprentice machinist with a photographic memory. Or it can be whisked off on a micro chip, magnetic tape, or disc, as seems to be the style today. Compounding the problem is the likelihood that the owner does not immediately realize that the technology has been taken, since he or she remains in full possession of it.

Other forms of mischief may also become more efficient. The insubstantiality of technology makes it a much more difficult weapon to defend against than the more obvious guns, tanks, or aircraft. Furthermore, an attack may not even evoke an alarm, much less a response, because the technological damage to such targets as data banks, information systems, and even gene pools can occur without the usual noise, ruckus, and physical affronts that typically accompany more traditional attacks. Biotechnology is especially threatening in this regard, because it functions via natural biological processes that may be the least likely to be suspected. The mind wants to shrink back at the potential for terrorism and sabotage thus made available, but the issue must be faced.

As the Howland presentation we heard this morning and Dr. Eichel's luncheon speech indicate, biotechnology presents special problems to its owners in defending their proprietary claims. Biotechnology is different from electronic, chemical, or mechanical technology in that it is most likely to be transmitted via living genes, rather than only via such controlled artifices as learned papers and electronic data storage and retrieval devices. Also, the finished product of advanced biotechnology resides in a living plant or animal (or fungus, bacteria, etc.) Therefore, the information on which the advanced biotechnology is based is turned loose into that most intimate part of the natural world that has always been regarded as an unlikely object of enforceable proprietary claims. If an I. B. M. or a Hewlett-Packard are suffering from leaks and thefts of their electronic technology, at least they are not seeing it being blown far and wide as so much hi-tech pollen on the four winds, which, unfortunately, is not an unlikely kind of fate for the products of biotechnology.

This difference between electronic, chemical, or mechanical inanimate technology and biotechnology helps explain why the former has made so many more conspicuous advances. Inanimate technology, even though it is hard to protect, is still more easily and more enforceably claimed than is biotechnology as a base from which private profits can be generated. The research and development of Silicon Valley are almost all done by private enterprise and are overwhelmingly driven by the profit motive, although intellectual curiosity and other platonic motives also operate to some degree. By contrast, the largest proportion of biotechnological research today is still done by universities and government research laboratories. It can only be driven by intellectual curiosity, scientific status seeking, and, perhaps, some interest in national or regional economic development.

Until capital investments in biotechnological research can be protected, the profit motive cannot be as directly engaged in biotechnology as it is in inanimate technology, and biotechnology will never really have a tiger in its tank. Careful legal work, like that in the Howland presentation, and very much more of it will be needed to increase the (always imperfect) protection of the profits from biotechnology. Indeed, this is likely to happen soon. Profit opportunities have a way of becoming enforceable. When the American Indian Chief Tecumseh was asked to sell a parcel of land to some early settlers, he denied that possibility, insisting that it was as impossible to own land as it was to own the wind or the rain. How quickly that outlook changed!

But all this analysis of the ownership of technology in general and of biotechnology in particular should not obscure the fundamental characteristic of technology:

that, unlike land and capital, it is insubstantial, not directly bequeathable, and very transitory. It is not something that can be owned permanently, but something that must be continuously cultivated and advanced. And, unlike the coming of agriculture and the coming of industry, the coming of technology does not threaten to annihilate the existing economic order.

We should also remember that those who would best use it to their advantage are those who best apply their personal intelligence and vigor to it. Material accumulations of inanimate capital and land — the basis of agricultural and industrial productivity — will count for less. Mental effectiveness and adaptability will be prime movers. For the first time, then, since Adam and Eve were condemned to a life of agricultural and industrial drudgery, these original characteristics evolved in humanity become central to the human condition. Once again, our futures now depend less on substantial proprietary claims and more on the qualities within us. I think that this is a good omen for biotechnology, for America, and for Ohio.